Provenance Analysis of the Leap Year Group, Northern Victoria Land, East Antarctica

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Abstract

The Leap Year Group is located within the Bowers terrane, in northern Victoria Land, East Antarctica and comprises quartz-rich rocks of the Camp Ridge Quartzite and Reilly Conglomerate. Seven samples were analysed, six from the Camp Ridge Quartzite and one from the Reilly Conglomerate, for provenance analysis. SEM-CL images were compared to thin section investigations and point count data, and suggest the likely source of the sediments within the Leap Year Group originate from a metamorphic terrane. It is therefore probable that the source of these rocks is the metsediment – rich Wilson terrane.

1. Introduction

The Leap Year Group is located within the Bowers terrane in northern Victoria Land, East Antarctica. There is still little known about the provenance of the Leap Year Group, although its composition suggests an unroofed metasedimentary source. Recent developments in scanning electron microscope-cathodoluminescence (SEM-CL) have facilitated provenance analysis by analysing individual quartz grains. This technique, in conjunction with optical petrography and point counting of 500 clast per sample, has been conducted in order to further understand the origins of the sediments within the Leap Year Group deposits. The aim of this analysis is to establish the provenance of this quartz, which dominates this unit and examine the potential relationships between the Leap Year Group and surrounding terranes. Severn samples will be analysed; six samples from the Camp Ridge Quartzite and one sample from the Reilly Conglomerate.

2. Geological History

Northern Victoria Land sits at the Pacific end of the Transantarctic Mountains, a first-order mountain belt running over a distance of ~3000 km bordering East Antarctica (Capponi et al. 1999). In northern Victoria Land, a 400 km wide belt of Late Precambrian and Palaeozoic sedimentary rocks are exposed between the Polar Plateau and the Ross Sea (Bradshaw et al. 1985). Northern Victoria Land includes three terranes from west to east, the Wilson terrane, the Bowers terrane and the Robertson Bay terrane (Federico et al. 2007)(figure 1), originally subdivided by Weaver et al. (1984). During the Ross Orogeny, both the Bowers and Robertson Bay terrane experienced low-grade metamorphism, whereas the Wilson, terrane, a segment of the palaeo-Pacific margin of the East Antarctic craton in the region, indicated a more complex evolution (Ricci et al. 1996).

2.1 Wilson terrane

The Wilson terrane is characterized by medium- to high-grade schists and gneisses and lesser low-grade metasediments formed from basic and ultrabasic igneous rocks, quartzose sandstone, conglomerate, and mudstone (Bradshaw et al. 1982). The stratigraphic relationship between sequences within the Wilson terrane is often poorly constrained. Fragments of body fossils indicative of a Palaeozoic age have been observed in the Terra Nova Bay area (Lombardo et al. 1989): however, elsewhere in the Wilson terrane the depositional age of the metasedimentary rocks is constrained only by crosscutting Granite Harbour Intrusives, and they are considered either Proterozoic or Cambrian in age (Stump 1995). The Granite Harbour Intrusives represent a calc-alkaline association with magmatic arc affinity, with ages range from 530 – 470 Ma (Bradshaw et al. 1985; Stump 1986).

2.2 Robertson Bay Terrane

The Robertson Bay terrane consists of a thick sequence of low-grade turbidies and extensive quartzose flyschlike sediments, the base of which is unexposed (Bradshaw et al. 1985; Stump 1995; Federico et al. 2007). Fossils are also present within this group, giving an age constraint of late-Cambrian to Ordovician. The source of this sequence is debated, however, their origin is most likely from a continental source Cambro-Ordovician in age (Federico et al. 2007). The bedding thickness of the Robertson Bay group varies from a few centimetres to a few meters, with the average greywacke units about 30 cm thick (Stump 1995). The turbidites are thought to originate from a marginal basin (Federico et al. 2007). It has been interpreted by Wright (1981) that turbidite rocks in the northern part of the Robertson Bay terrane to have been deposited in a middle to distal deep-sea fan or plain facies. Some of the turbidies further south, however, have been interpreted by Field and Findlay (1983) to have been deposited in a more proximal deep—sea fan facies (Stump 1995).

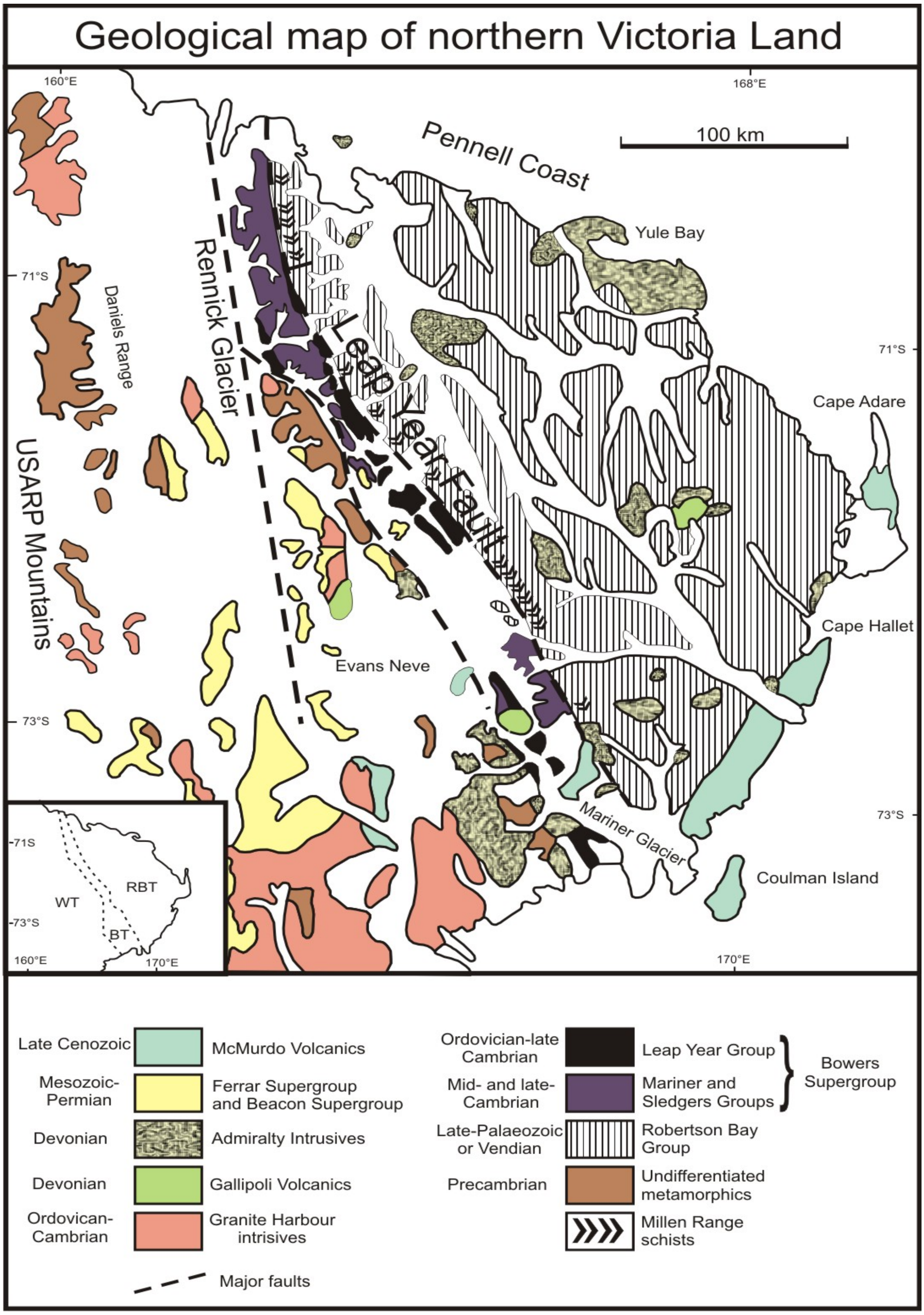

Figure 1. Geological Map of northern Victoria Land (Weaver et al. 1984)

2.3 Bowers Terrane

The Bowers terrane is a 20-25 km wide elongate, fault-bounded succession of rocks located between the Wilson and Roberson Bay terranes (Stump 1995). This infaulted belt extends south-east at least 350 km across Northern Victoria Land from the Southern Ocean to the Ross Sea (Bradshaw et al. 1985).. This Late Cambrian regressive marine to non-marine sequence contains a diverse suite of sedimentary and volcanic rocks at least 10 m thick, which are interpreted to represent the varying stages of development and infill of a mid-Cambrian to early –Ordovician basin (Andrews & Laird 1976; Laird 1987). The Bowers terrane contains three major groups; the Sledgers, Mariner and Leap Year groups (figure 2).

2.3.1 Sledgers Group

The Sledgers Group consists of the Glasgow Volcanics (Cambrian oceanic arc rocks) and associated and interfingering sediments of the Molar Formation (Laird et al. 1982)), which contain fossils of mid-late Cambrian age. The Glasgow Formation includes flows of basalt, andesite and rhyolites and closely associated breccias. It is 2500 m thick in places, with the majority of the formation thought to have accumulated under marine conditions (Bradshaw et al. 1985). The Molar Formation is at least 1300 m thick and characterised by dark mudstone turbidite units, some comglomerates infilling channels (Laird et al. 1982).

2.3.2 Mariner Group

The Mariner Group represents a regressive, mainly shallow marine sequence of late Cambrian age. The Westernmost part of the Bowers Terrane is characterized by highly deformed greenschist facies metaconglomerates with felsic to mafic compositions. The source area of these rocks is debated, however they are thought to originate from the Glasgow Volcanics (Crispini et al. 2007). The Mariner formation overlies the Sledgers formation without apparent discordance. This fossiliferous marine sequence comprises sandstone at the base, which passes upwards into shale with thin limestone and sandstone beds. Channels with large limestone blocks are locally presented (Laird et al. 1982).

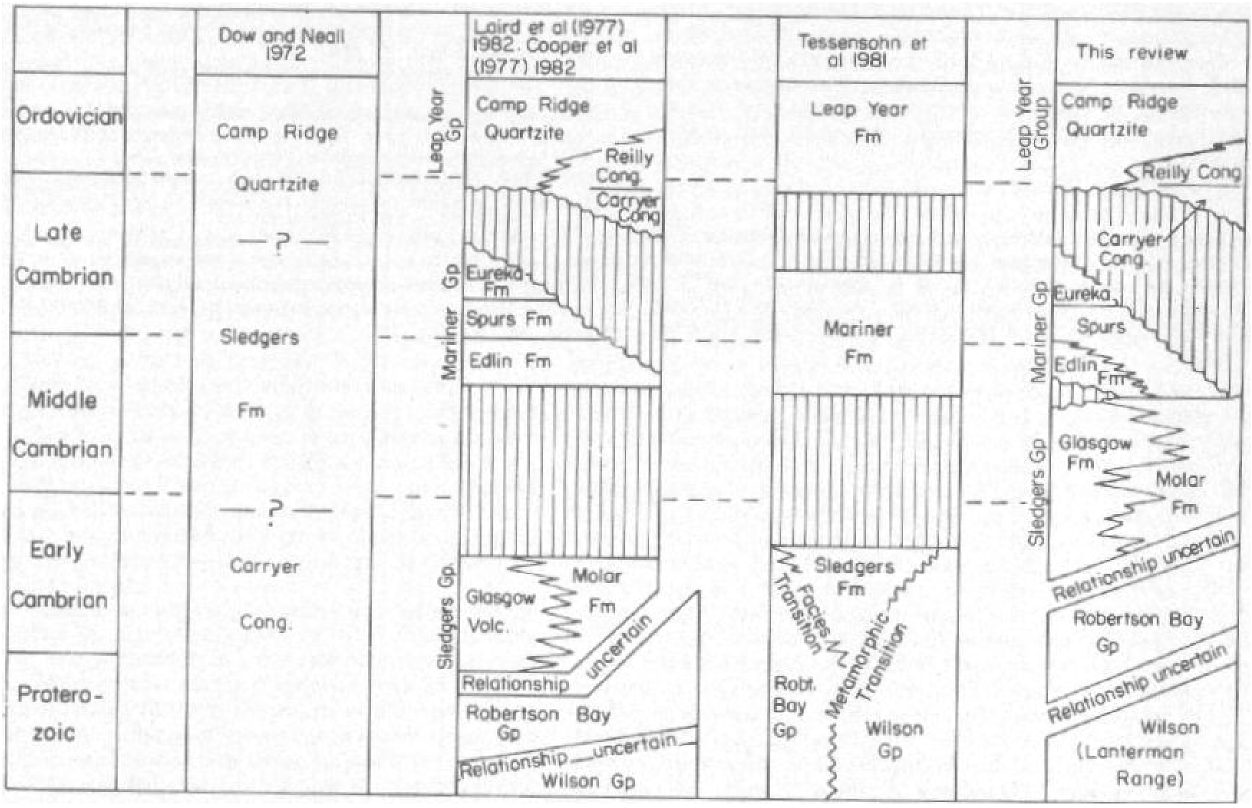

Figure 2. Variations in stratigraphic subdivisions and relationships of rock units in northern Victoria Land (Bradshaw & Laird 1983)

2.3.3 Leap Year Group

The Leap Year Group is the youngest of the three groups included within the Bowers terrane, and has an estimated thickness of 4000 m (Laird 1987). The Leap Year Group rests on a marked erosion surface, which truncates successively older horizons of the Mariner and Sledgers Groups towards the northwest (Laird 1987). This group has been traced throughout most of the length of the Bowers terrane and is dominated by quartzose sandstone, the origin and age of which is uncertain. There are, however, trace fossils located within the Camp Ridge Quartzite, which suggest the Leap Year Group to be Cambrian in age (Stump 1995).

The Leap Year Group is exposed in two separate strips, which form the eastern and western margins of the Bowers Group outcrop. The eastern strip is characterized by 3000 m of red-brown or yellow quartzose sandstone, with minor quartzose conglomerate and mudstone (Camp Ridge Quartzite) exposed within the core of a major syncline (Laird et al. 1977). In the western outcrop strip, inferred fluvial deposits dominate, with a minimum thickness of 800 m. These deposits have been previously described as the Carryer Conglomerate (Laird et al. 1977). The Reilly Conglomerate is also represented within the Leap Year Group, and has been correlated with the Camp Ridge Quartzite (Laird 1987).

The Carryer conglomerate is a red polymict, mixed bedload, braided river conglomerate, with a continental arc source. This unit has previously been attributed to the Leap Year Group, due to its inferred stratigraphic relationship to the Reilly Conglomerate, although the two are not compositionally related. Bassett et al (2002), however have recently interpreted the Carryer Conglomerate to instead be correlative with the conglomerates in the upper part of the Mariner Group (Bassett et al. 2002).

2.3.4 Camp Ridge Quartzite

The Camp Ridge Quartzite is dominated by red-brown to yellowish grey quartzose moderately sorted medium sandstone. Several interbeds, up to 1m thick, of either dark greenish-grey parallel and ripple cross-laminated, micaceous sandy mudstone or brownish-grey fissile mudstone are recorded throughout the sequence (Andrews & Laird 1976). Andrews & Laird (1976) have noted that many of the conglomerates and sandstones contain sufficient rock fragments to be classified as sublitharenites, with many of the lithics composed of micaceous siltstone, sandy siltstone, silty sandstone and chert.

The characteristics that define the Camp Ridge Quartzite include coarse detritus, scattered scoured out beds of mudstone, mudstone clasts, abundant trough crossbedding and a unimodal pattern of cross-bedding azimuths. These features are consistent with an alluvial environment of deposition, with the low dispersion of the cross-bedding azimuths suggesting a braided river channel system being most likely (Allen 1965; Andrews & Laird 1976). The occurrence of trough cross-bedding in the poorly sorted units, the scattered occurrence of channels and the red colour of the majority of sediments (Laird et al. 1974) also support a fluviatile origin. It is also noted, however that the trace fossil association, especially in the lower part of the sequence, is more suggestive of a shallow marine environment (Laird et al. 1974). Laird et al (1974) further propose that the entire sequence has been influenced by a river flowing to the north-west or north-north-west, with the lower half of the sequence most likely representing the shallow marine part of a delta. The upper half, where there have been no trace fossils recorded, and where the occurrence of red beds is higher, is thought to represent the subaerial part of the delta (Laird et al. 1974).

At the type locality, Camp Ridge, in the East Quartzite Range, thin sections have indicated the rocks to be moderately well sorted and consisting mainly of equigranular, sub-rounded or sub-angular quartz grains in a sparse matrix (Laird et al. 1974). Polycrystalline quartz is described as a minor, although ever-present constituent, and rock fragments, where present, consist of quartzose sandstone and siltstone. Feldspar and muscovite are rare constituents (Laird et al. 1974).

Six samples collected from the Camp Ridge Quartzite (figure 4) have been analysed. Samples CRQ2 from the north-east end of the Molar Massif, CRQ6, CRQ9 and CRQ10, from the central eastern portion of the Molar Massif, and samples CRQ30 and CRQ32 from a block of Camp Ridge Quartzite south of the Molar Massive.

2.3.5 Reilly Conglomerate

The Reilly Conglomerate is characterized by pebbly quartzose conglomerate that crops out on Reilly Ridge and on nunataks to the south, and is inferred to be Cambrian or Ordovian in age (Laird et al. 1982). This formation also is observed outcropping in the lower Carryer Glacier where ~20m of reddish, medium- to coarse-grained, quartzose sandstone and quartzose conglomerate rest with apparent conformity on the Carryer Conglomerate (Laird et al. 1982). No upper stratigraphic limit is observed to the Reilly Conglomerate, however a minimum thickness of ~300 m is present in outcrops north of the type locality (Laird et al. 1982). Although the Reilly Conglomerate is coarser-grained than the Camp Ridge Quartzite, the two formations are similar in composition, occupy a similar stratigraphic position overlying rocks of the Mariner Group, and are considered to be stratigraphic equivalents (Laird et al. 1982). One sample was collected for analysis, from the Reilly Conglomerate type locality at Reilly Ridge (R23/81) (figure 4).

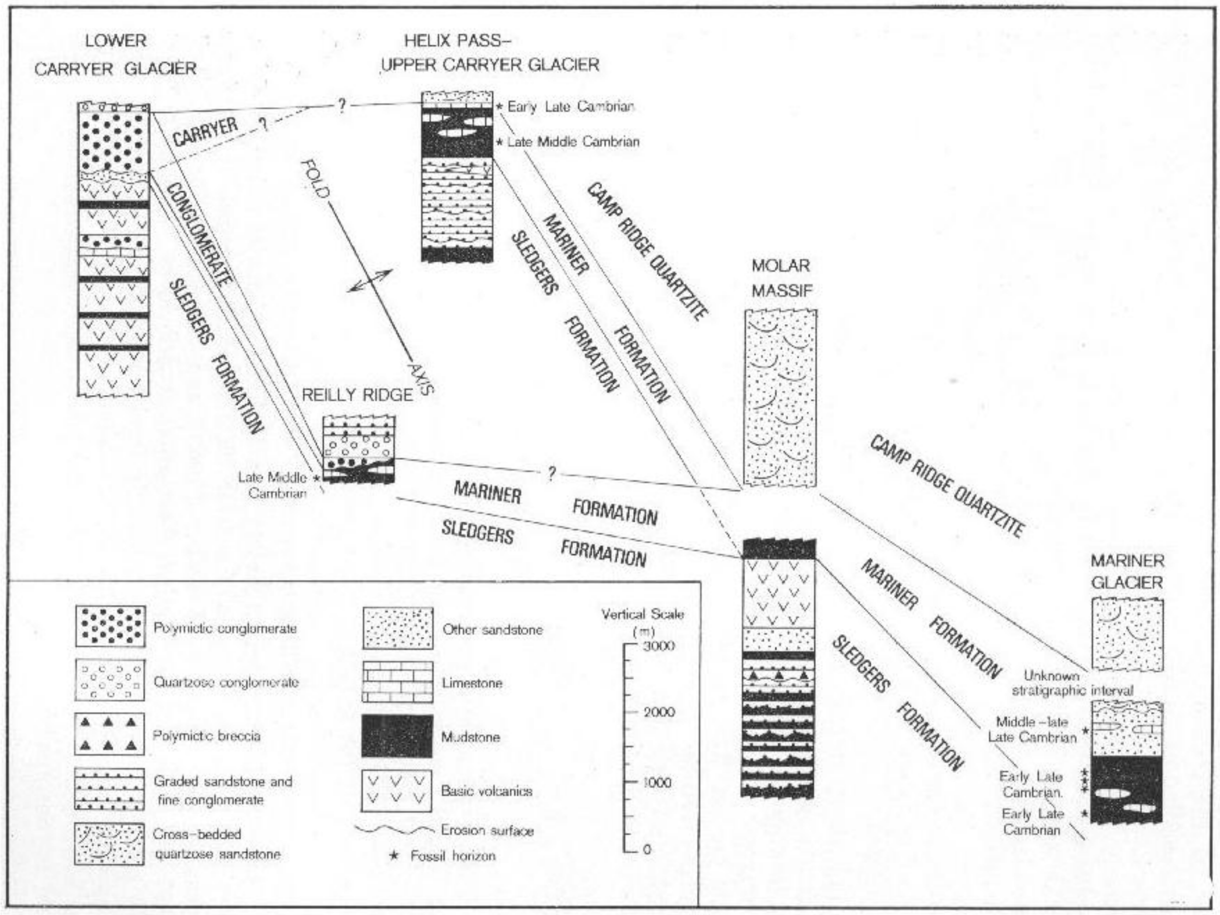

Figure 3. Comparative stratigraphic columns for the Bowers Group (after Laird et al (1976))

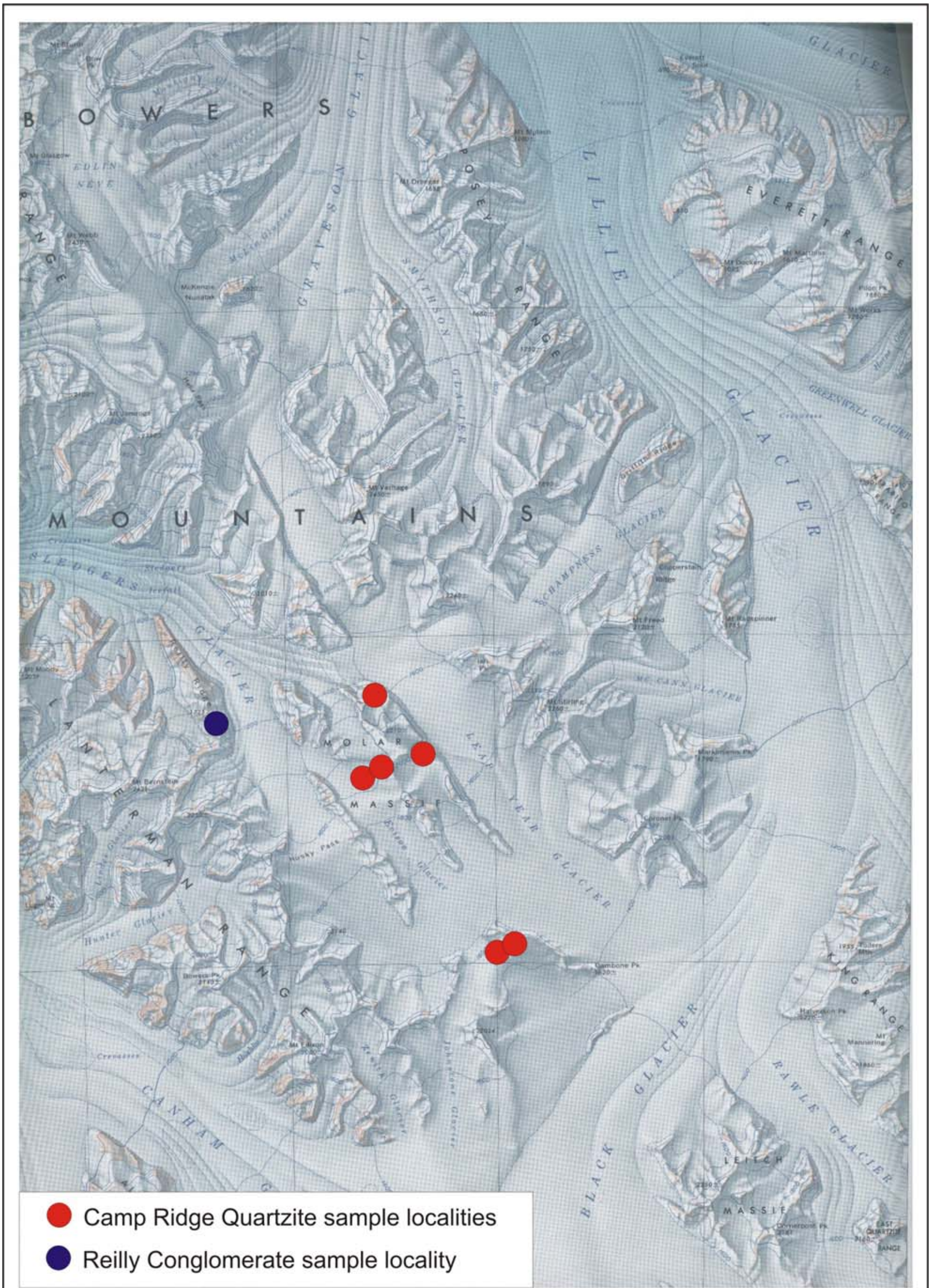

Figure 4. Map of the Bowers Mountains with sample localities

3 Methods

Seven samples were obtained for analysis, six samples from the Camp Ridge Quartzite, and one sample from the Reilly Conglomerate. From hand specimens, two sets of 30 μm rock thin sections were cut from each sample, one set unpolished for petrographical analysis and optical microscopy, and one polished set for cathodoluminescence investigation.

In order to obtain optimal mineralogical identification, feldspar etching/staining was conducted on one set of samples. Staining is a fast and practical means of distinguishing feldspars from each other and from other minerals in thin sections (Lewis & McConchie 1994). The thin sections were first cleaned with acetone before etching was performed using hydrofluoric acid (HF) and stained with sodium-cobaltinitrite and potassium rhodizonate acid . This staining technique was conducted according to Lewis et al (1994).

A point count of 500 grains was accomplished on all seven stained thin sections using a Model F Automatic Point Counter Unit attached to a standard petrographic microscope. Several categories were determined based on grain size and composition. Four quartz types were recognised: single quartz crystal, straight extinction, single quartz crystal, undulose extinction; coarse-grained polycrystalline quartz (< 3 crystal units per grain), and fine-grained polycrystalline quartz (> 3 crystal units per grain). Lithics were classified into four groups also: siltstone lithics, typically comprising feldspar quartz and micas; metaquartz siltstone lithics, dominated by coarse and typically very fine-grained; schist lithics; and amphibole lithics. Matrix was counted with very fine -grained clasts unrecognisable under 10x magnification also included as part of the matrix. Feldspar was recorded as both detrital grains and altered feldspar clasts, and single detrital crystals were recorded in their own various categories. Point count data and associated graphs are included in the following results section of this report.

Representations of the varying quartz types were analysed using a Leica Stereoscan 440 SEM and a Gatan MiniCL cathodoluminescence detector for SEM-CL analysis. The MiniCL detects luminescence detects luminescence in the 185-850 nm wavelength range. Identification of the minerals was supported by chemical spot analysis using an Oxford Link ISIS X-ray EDS analysis system (Bernet & Bassett 2005). This analysis was conducted on the second set of unpolished thin section samples. As quartz is a relatively low-luminescent mineral in comparison to many feldspar and carbonate minerals, this technique is useful in examining the internal features and structures within the quartz grains, and aids in their provenance identification (Seyedolali et al. 1997; Bernet & Bassett 2005). Comparisons were then made to optical microscope images of the same quartz grains analysed with the SEM-CL.

4 SEM-CL identification

The scanning electron microscope-cathodoluminescence (SEM-CL) technique for quartz provenance analysis is a fairly recent development (Bernet & Bassett 2005). This technique has been used to distinguish between plutonic, volcanic, and metamorphic quartz in coarse- to medium-grained sand or sandstone, using a technique independent of petrographer bias (Bernet & Bassett 2005). This process also enables the study of the CL characteristics of quartz at a high magnification, therefore showing increased detail (Seyedolali et al. 1997).

4.1. Plutonic Quartz

Large crystals containing open and/or healed microcracks, fluid inclusion trails and non-undulose to slightly undulose extinction often characterize plutonic Quartz. These microcracks are not related to crystal cleavage but are instead formed due to thermal stress within the crystal during postmagmatic cooling (Sprunt & Nur 1979; Bernet & Bassett 2005). These microcracks are typically randomly orientated, and may include several generations of microcracks or healed cracks (Bernet & Bassett 2005).

4.2 Metamorphic Quartz

Metamorphic quartz often displays either a mottled fabric or nondifferential CL, with tectonically deformed quartz frequently exhibiting intricate patterns of shears and fractures (Seyedolali et al. 1997). Boggs & Krinsley (2006) outline several features characterizing metamorphic quartz in SEM-CL. These include mottled-texture, which Bernet & Bassett (2005) have correlated with strong undulose extinction arising from increasing deformation (Boggs & Krinsley 2006). Homogeneous CL is also moderately common in metamorphic quartz, and occur as either very bright CL grains, thought to correlate with high-grade metamorphic quartz or very dark CL grains, and may represent cleaning of the quartz crystal structure from trace elements and structural defects during recrystalization (Boggs & Krinsley 2006). Healed fractures and deformation lamellae are also thought to be characteristics of metamorphic quartz (Boggs & Krinsley 2006).

4.3 Recycled Sedimentary Quartz

One way in which recycled sedimentary quartz may be identified is by inherited authigenic overgrowth around detrital quartz (Bernet & Bassett 2005). Authigenic quartz is easily seen by CL, as it appears black, contrasting with the lighter CL of most other detrital quartz. Grain shattering along grain contacts has also been described as a mechanism for identifying recycled sedimentary quartz, as diagenesis and compaction occurs when sediment is deposited (Bernet & Bassett 2005)

5 Results

5.1 Point Count Data

Table 1. Results of a 500 grain point count for Sample CRQ2

Sample #	Crystal type	Number counted	Percentage (%)
CRQ2	Single quartz crystal, straight extinction	291	58
	Single quartz crystal, undulose extinction	26	5
	Polycrystalline quartz, coarse grained	20	4
	Polycrystalline quartz, fine grained	32	6
	Siltstone lithic	19	4
	Quartz metasiltstone lithic	11	2
	Schist lithic	4	1
	Matrix	45	9
	Opaque	3	1
	Feldspar	40	8
	Feldspar (altered)	3	1
	Muscovite	6	1

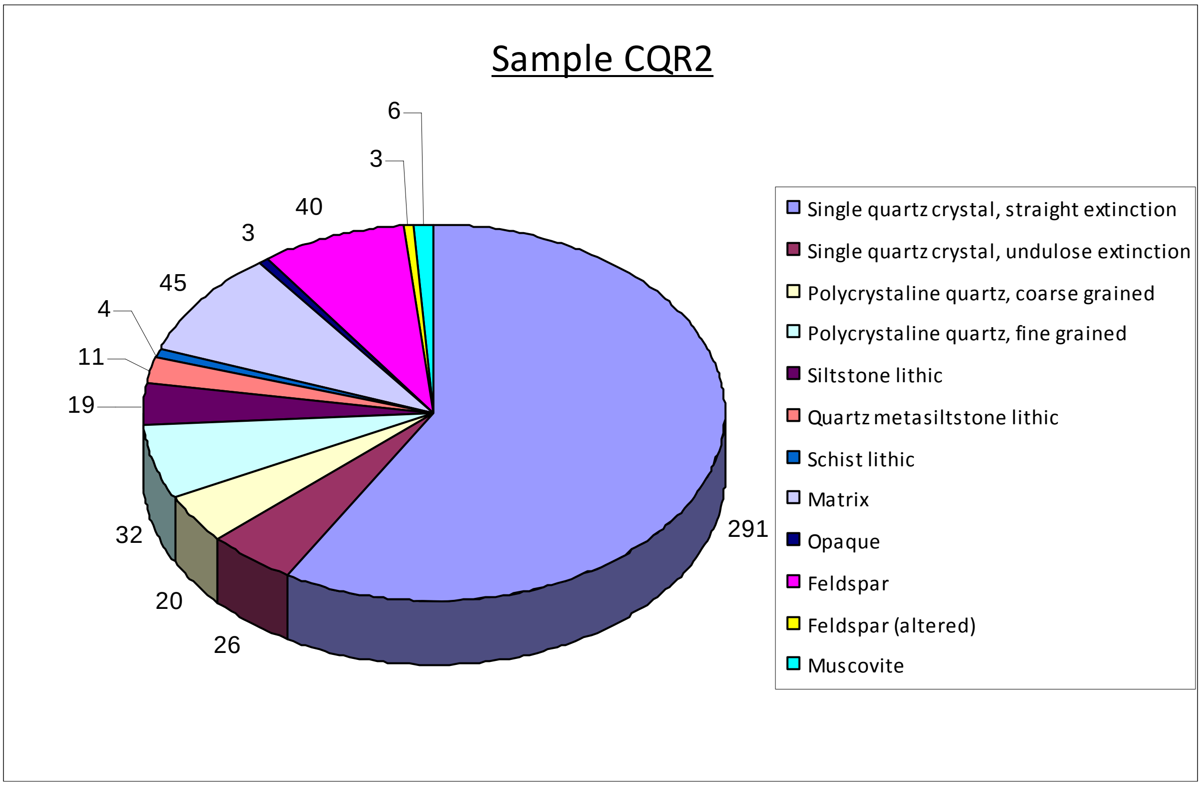

Figure 5. Pie chart illustrating the variations of clast composition of sample CRQ2

Table 2. Results of a 500 grain point count for Sample CRQ6

Sample #	Crystal type	Number counted	Percentage (%)
CRQ6	Single quartz crystal, straight extinction	290	59
	Single quartz crystal, undulose extinction	8	2
	Polycrystalline quartz, coarse grained	30	6
	Polycrystalline quartz, fine grained	18	4
	Siltstone lithic	7	1
	Quartz metasiltstone lithic	2	<1
	Schist lithic	1	<1
	Amphibole lithic	2	<1
	Amphibole	2	<1
	Matrix	68	14
	Opaque	6	1
	Feldspar	42	8
	Feldspar (altered)	1	<1
	Biotite	3	1
	Muscovite	20	4

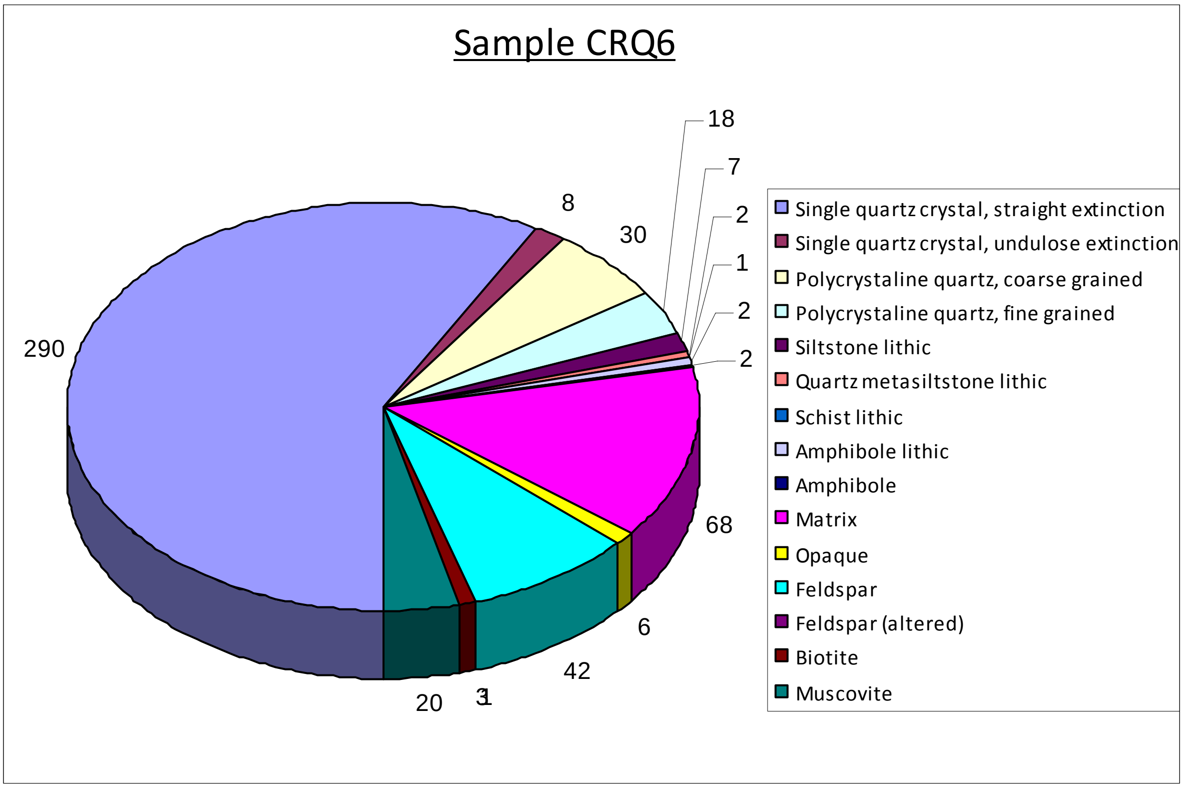

Figure 6. Pie chart illustrating the variations of clast composition of sample CRQ6

Table 3. Results of a 500 grain point count for Sample CRQ9

Sample #	Crystal type	Number counted	Percentage (%)
CRQ9	Single quartz crystal, straight extinction	309	62
	Single quartz crystal, undulose extinction	19	4
	Polycrystalline quartz, coarse grained	12	2
	Polycrystalline quartz, fine grained	33	7
	Siltstone lithic	15	3
	Quartz metasiltstone lithic	8	2
	Schist lithic	15	3
	Matrix	47	9
	Opaque	4	1
	Feldspar	21	4
	Biotite	7	1
	Muscovite	10	2

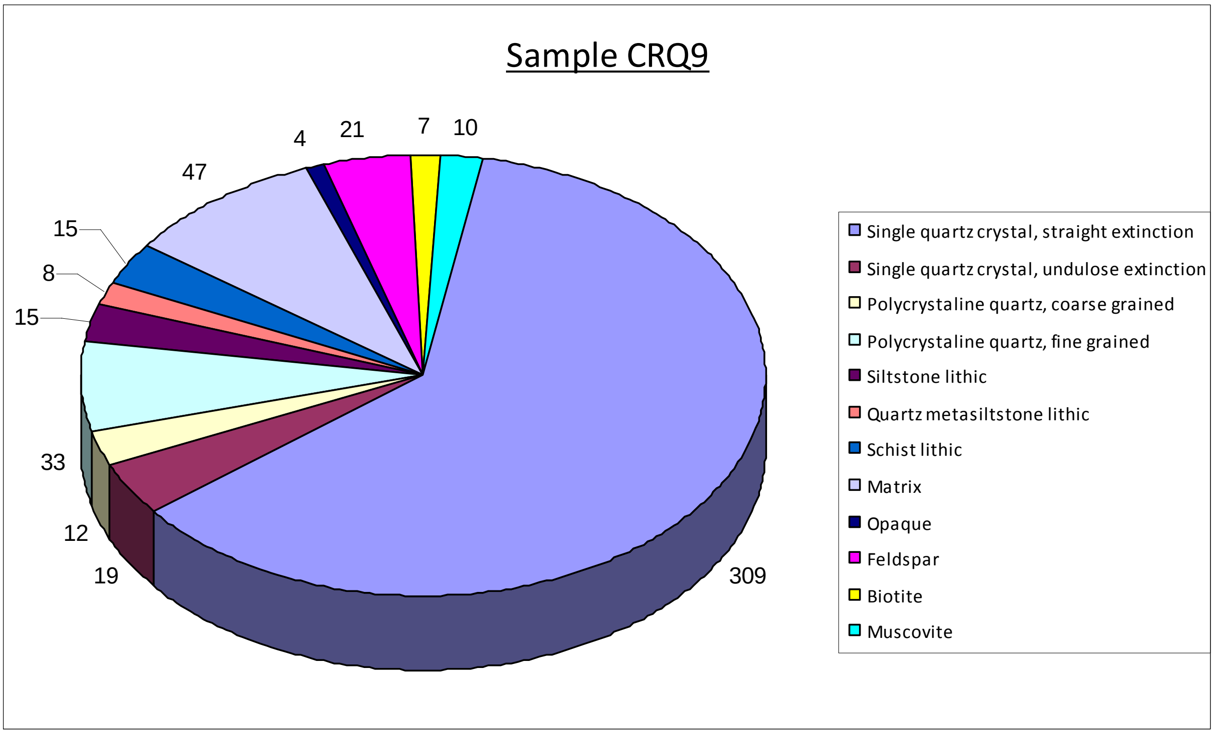

Figure 7. Pie chart illustrating the variations of clast composition of sample CRQ9

Table 4. Results of a 500 grain point count for Sample CRQ10

Sample #	Crystal type	Number counted	Percentage (%)
CRQ10	Single quartz crystal, straight extinction	326	65
	Single quartz crystal, undulose extinction	28	6
	Polycrystalline quartz, coarse grained	21	4
	Polycrystalline quartz, fine grained	38	8
	Siltstone lithic	10	2
	Quartz metasiltstone lithic	9	2
	Schist lithic	2	<1
	Matrix	29	6
	Opaque	2	<1
	Feldspar	25	5
	Biotite	2	<1
	Muscovite	4	1
	Calcite	4	1

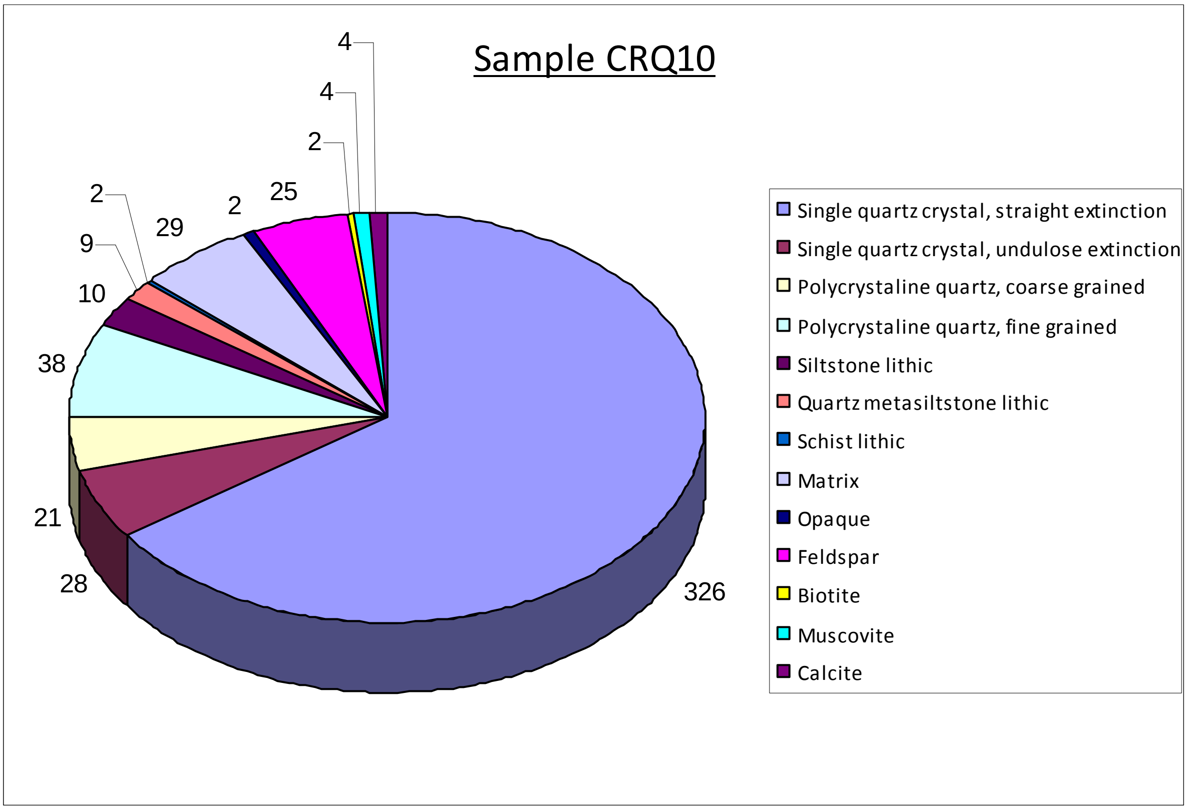

Figure 8.. Pie chart illustrating the variations of clast composition of sample CRQ10

Table 5. Results of a 500 grain point count for Sample CRQ30

Sample #	Crystal type	Number counted	Percentage (%)
CRQ30	Single quartz crystal, straight extinction	207	42
	Single quartz crystal, undulose extinction	38	8
	Polycrystalline quartz, coarse grained	97	19
	Polycrystalline quartz, fine grained	43	9
	Siltstone lithic	26	5
	Quartz metasiltstone lithic	18	4
	Schist lithic	3	1
	Matrix	46	9
	Opaque	17	3
	Feldspar (altered)	2	<1
	Muscovite	2	<1
	Titanite	1	<1

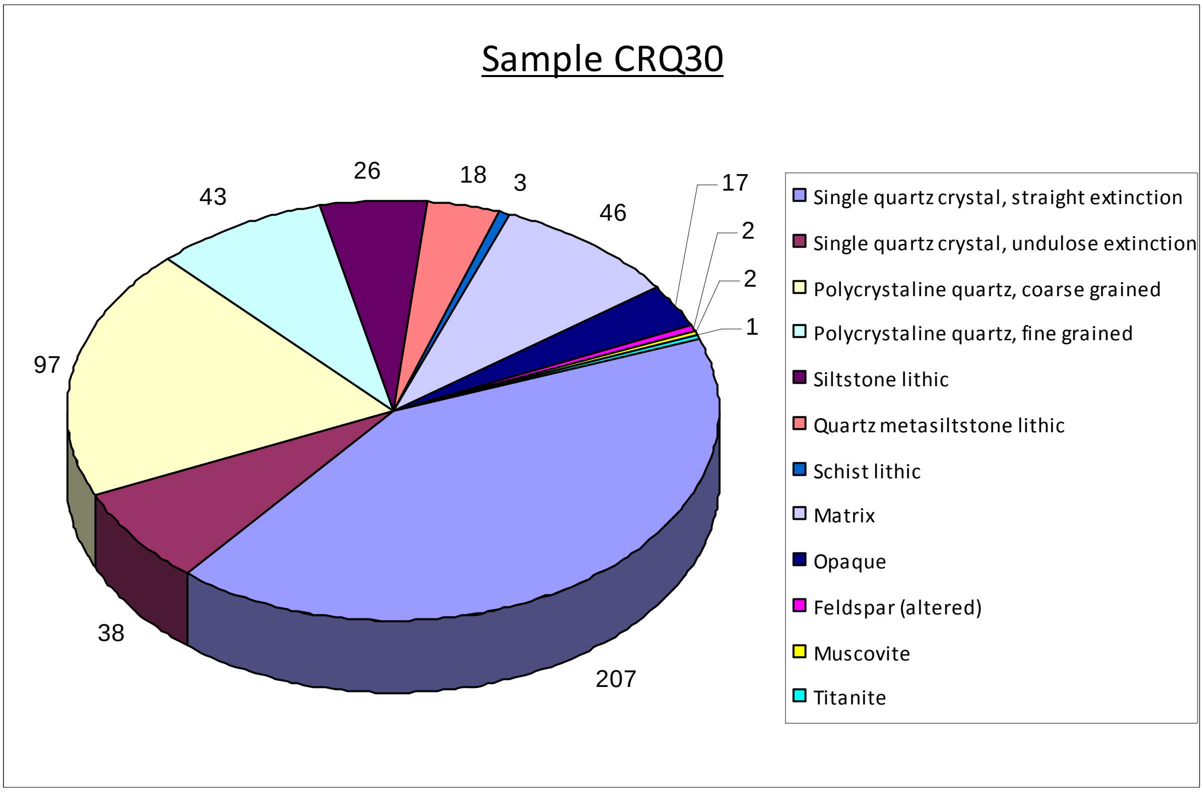

Figure 9. .. Pie chart illustrating the variations of clast composition of sample CRQ30

Table 6. Results of a 500 grain point count for Sample CRQ32

Sample #	Crystal type	Number counted	Percentage (%)
CRQ32	Single quartz crystal, straight extinction	314	63
	Single quartz crystal, undulose extinction	5	1
	Polycrystalline quartz, coarse grained	12	2
	Polycrystalline quartz, fine grained	57	11
	Siltstone lithic	28	6
	Quartz metasiltstone lithic	5	1
	Schist lithic	3	1
	Amphibole lithic	1	<1
	Matrix	47	9
	Opaque	10	2
	Feldspar	10	2
	Biotite	3	1
	Muscovite	5	1

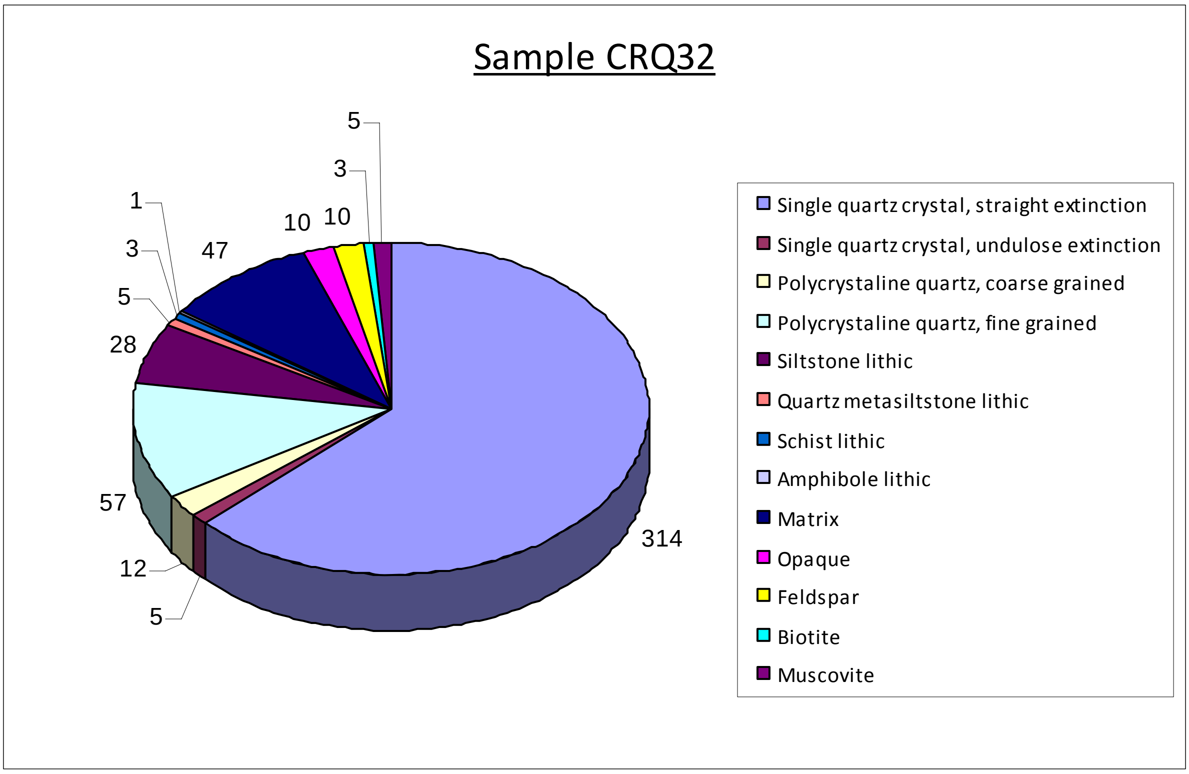

Figure 10. Pie chart illustrating the variations of clast composition of sample CRQ32

Table 7. Results of a 500 grain point count for Sample R23/81

Sample #	Crystal type	Number counted	Percentage (%)
R23/81	Single quartz crystal, straight extinction	169	34
	Single quartz crystal, undulose extinction	62	12
	Polycrystalline quartz, coarse grained	57	11
	Polycrystalline quartz, fine grained	35	7
	Siltstone lithic	32	6
	Quartz metasiltstone lithic	24	5
	Schist lithic	33	7
	Matrix	52	10
	Opaque	4	1
	Feldspar	8	2
	Feldspar (altered)	4	1
	Biotite	6	1
	Muscovite	10	2
	Chlorite	4	1

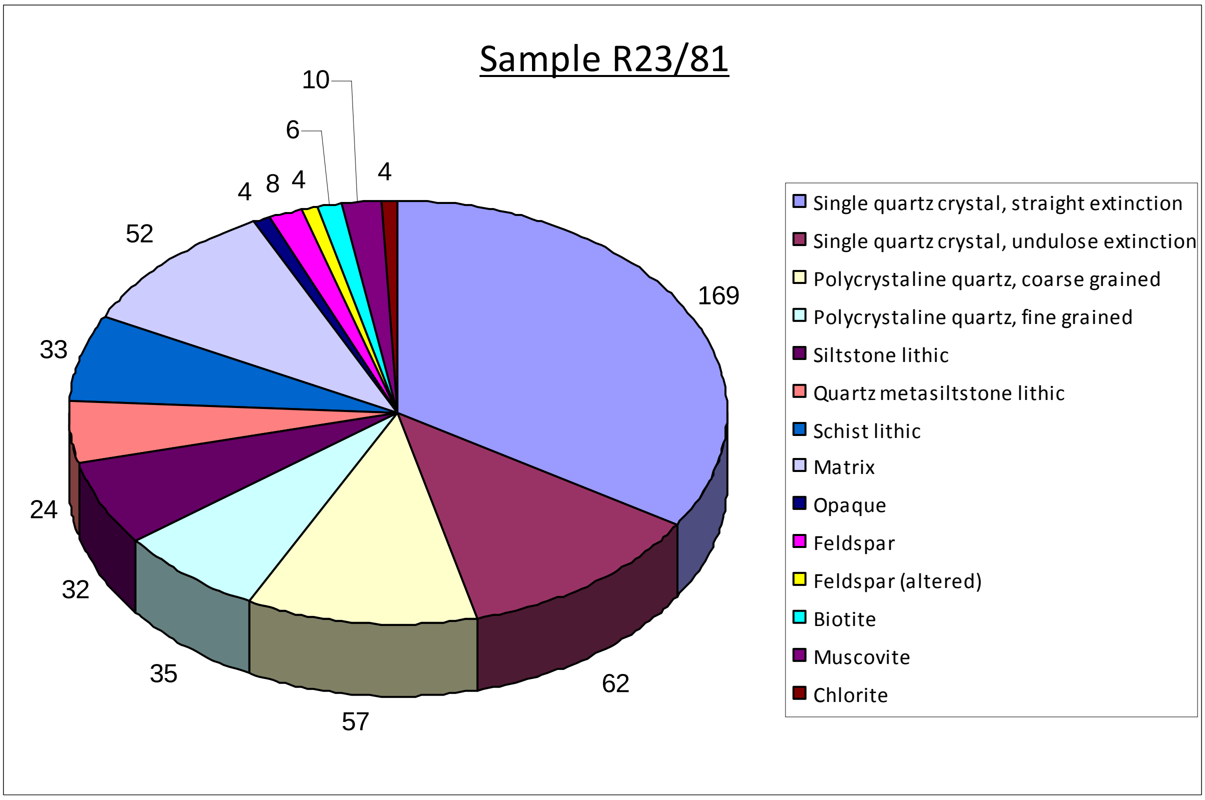

Figure 11. Pie chart illustrating the variations of clast composition of sample R23/81

The above point counts were conducted using a standard optical petrographical microscope, with 500 counts being tallied per sample. This data has been used to determine the tectonic setting in which these 7 samples were originally deposited, as illustrated in figures 12, 14 and 15.

The QFL diagram illustrated in figure 12 gives an inferred tectonic origin of the samples analyzed. All but one of the samples plots in the Recycled Orogen category, with one sample plotting within the margins of the Craton Interior category. Recycled orogens typically contain sedimentary strata, subordinate volcanic rocks, and their metamorphic derivations, which are exposed due to erosion by orogenic uplift (Pettijohn et al. 1987). Quartzose sands derived from the cratonic areas are common within interior basins, on platforms, miogeosynclinal wedges, and open ocean basins bounded by passive margins (Pettijohn et al. 1987) .

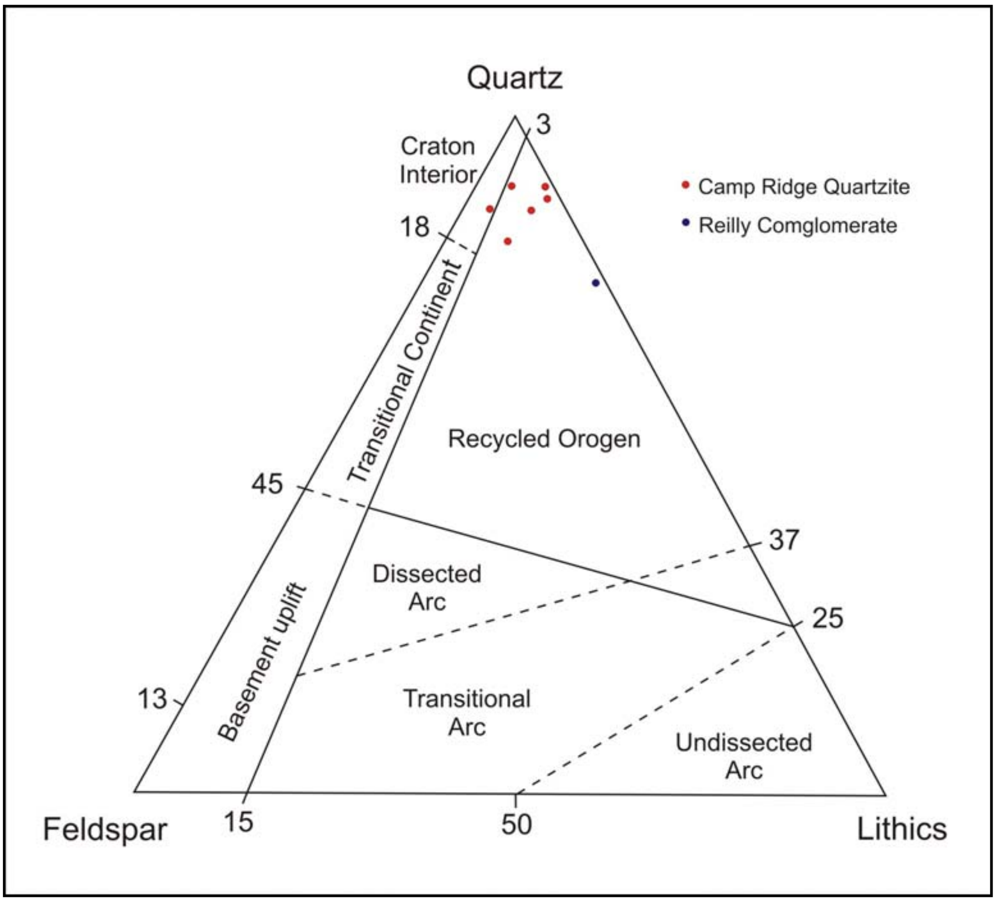

Figure 12. QFL diagram, illustrating the relative quartz, feldspar and lithic components of the seven samples analysed in this report. (After Dickinson (1983))

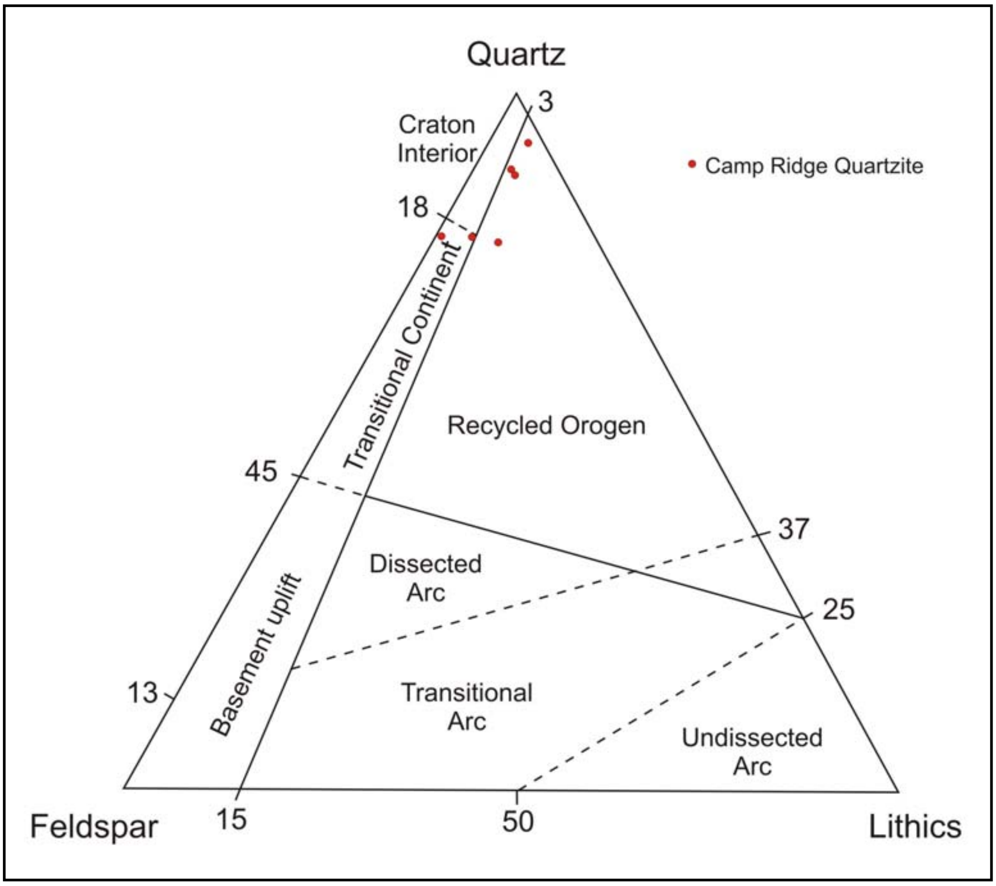

Figure 13. QFL diagram illustrating the relative quartz, feldspar and lithic components previously analysed (Pettijohn et al. 1987)

A previous point count study was conducted by Wodzicki & Robert (1986), which yielded similar results. Six samples were analysed, all originating from the Camp Ridge Quartzite unit. Figure 13 illustrates the relative quartz, feldspar and lithic components of these samples. Four of six samples plot within the recycled orogen category, with the remaining two plotting in the transitional continent category. Although the 12 Camp Ridge Quartzite samples analysed plot into three different categories, they still appear similar in composition and are clustered together, the bulk of which are inferred to originate from a recycled orogen (figure 12 and 13)

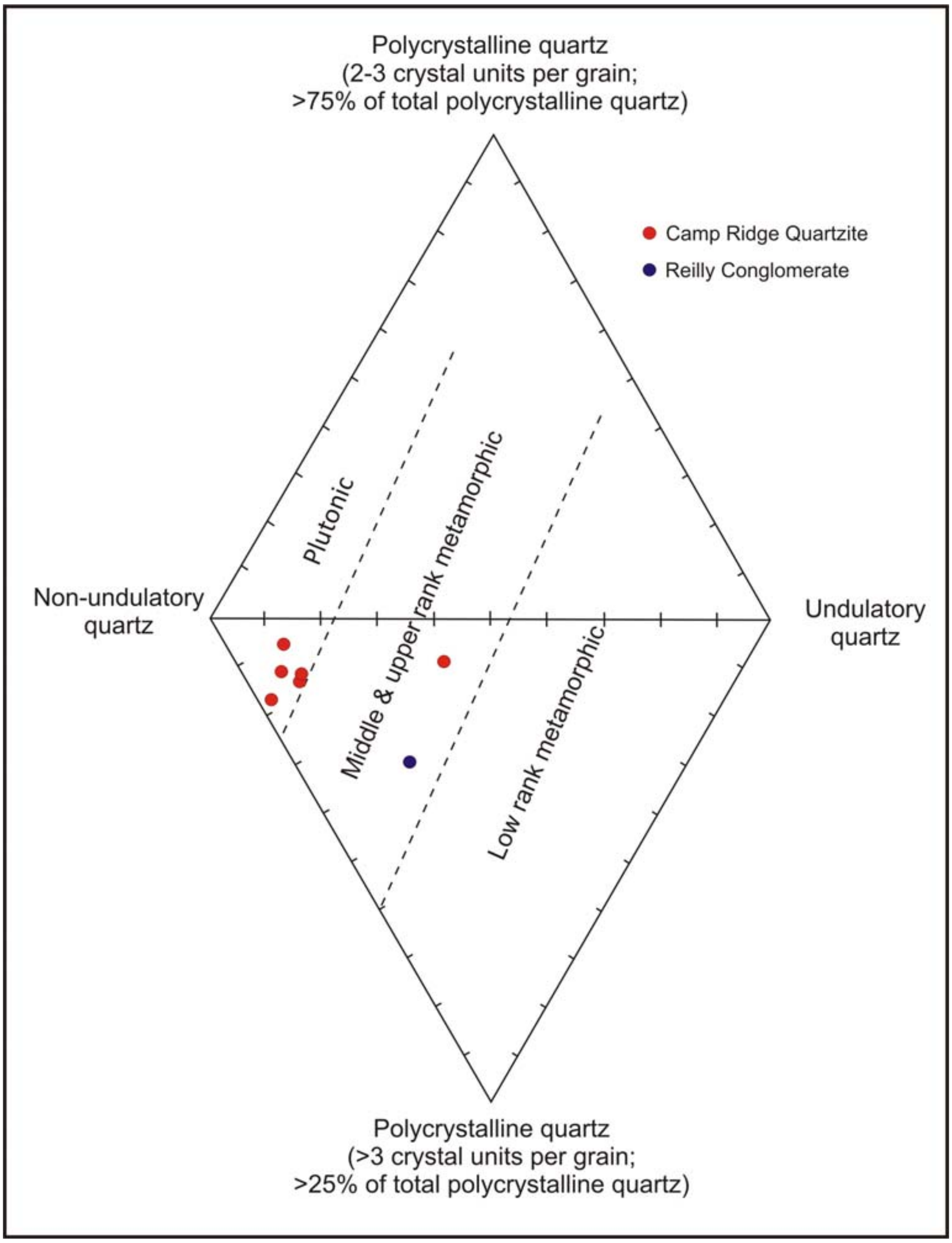

Figure 14. Four variable plots of nature of quartz population from the seven samples analysed (after Besu et al (1975))

All of the seven samples investigated in this report have a significantly larger proportion of single crystal straight extinction quartz (or non-undulatory quartz) than that of the other three categories. However, both samples CRQ30 and R23/81 have a higher relative ratio of undulatory quartz than the other five samples from the Camp Ridge Quartzite.

The five samples with the largest amount of non-undulatory quartz were inferred to be plutonic in nature, with only CRQ30 and R23/82 inferred to originate from middle and upper rank metamorphics.

The composition of the lithic clasts within the sandstone and conglomerate samples illustrated the lack of volcanic clasts present. As no volcanic quartz was observed neither the SEM-CL nor the thin section analysis, this is unsurprising. There is however, variation in the relative percentages of sedimentary and metamorphic lithics (figure 15). The coarser grained Reilly Conglomerate (sample R23/81), illustrates the highest percentage of metamorphic clasts, (~60%), with Camp Ridge Quartzite samples showing as little as ~25% metamorphic clasts (figure 15).

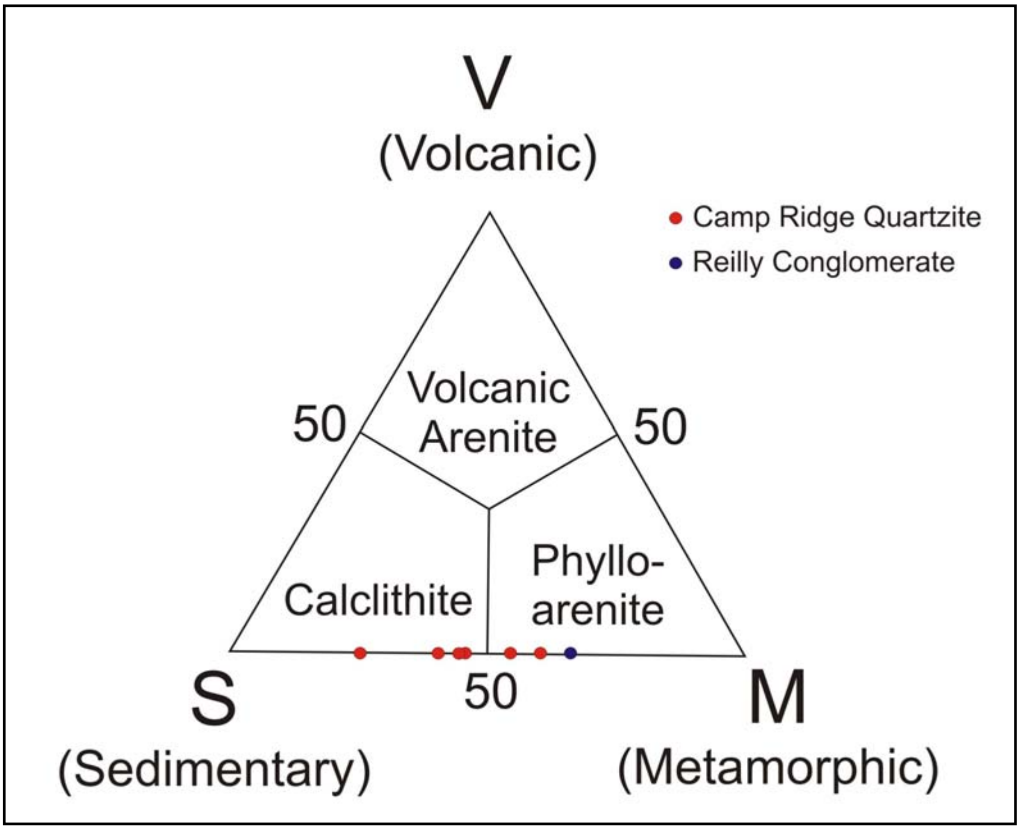

Figure 15. Variations in lithic composition

5.2 SEM-CL imagery Comparisons with Optical Petrographic Images

Although SEM-CL imaging of quartz is a useful tool, the added use of petrographic analysis of the same quartz grains further aids provenance identification. Petrographic analysis involves the identification of framework mineralogy, quartz undulosity and polycrystallinity and feldspar composition recognition, which is difficult to obtain using only the SEM-CL method. However, with these two techniques used together, a more realistic interpretation of source-rock lithology is obtained than either technique alone (Boggs & Krinsley 2006). Two samples were analysed using the SEM-CL and then compared to petrographic images obtained using a standard optical microscope. One sample, (CRQ32) originated from the Camp Ridge Quartzite, and the other sample (R23/81) from the Reilly Conglomerate at Reilly Ridge (figure 4).

5.2.1 Sample CRQ32

The fine-grained polycrystalline quartz observed in thin section appeared very different when analysed with the SEM-CL. In figure 16, one observes very little internal structure in the polycrystalline quartz grain when under SEM-CL, apart from a single fracture. This fracture however is not observed in figure 16B and 16C. Figure 17, illustrates a coarse-grained polycrystalline quartz grain, where there appears to be several cracks and fractures visible when observed with the SEM-CL, which may represent a plutonic origin.

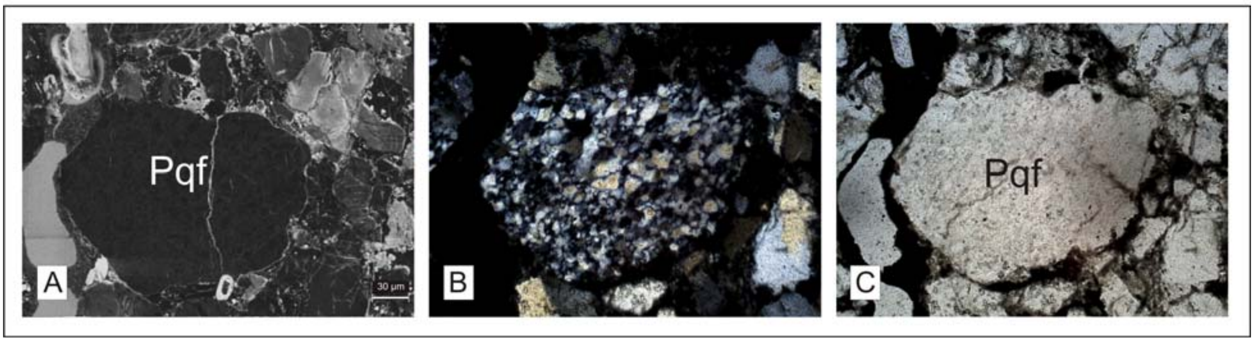

Figure 16. Sample CRQ32. Pqf (Polycrystalline quartz fine grained) A = SEM-CL image, B=Cross polarized light image C= Plain polarized light image

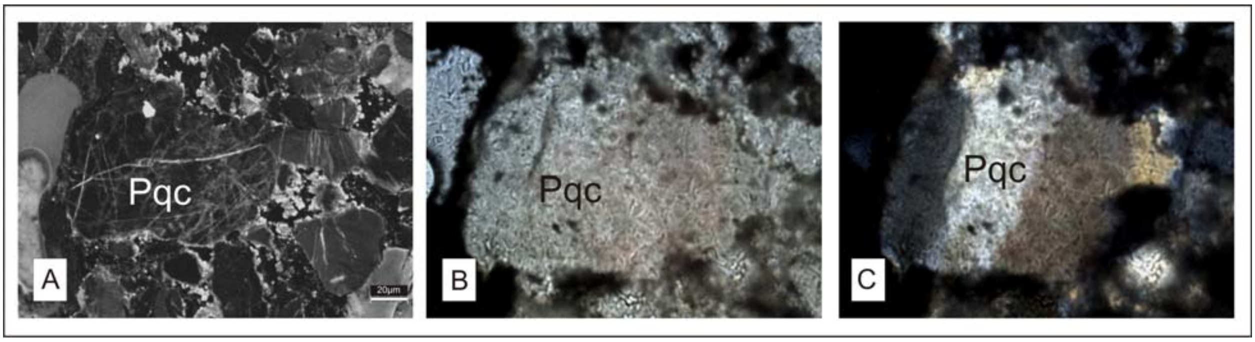

Figure 17. Sample CRQ32. Pqc (polycrystalline quartz coarse grained) A = SEM-CL image, B=Cross polarized light image C= Plain polarized light image

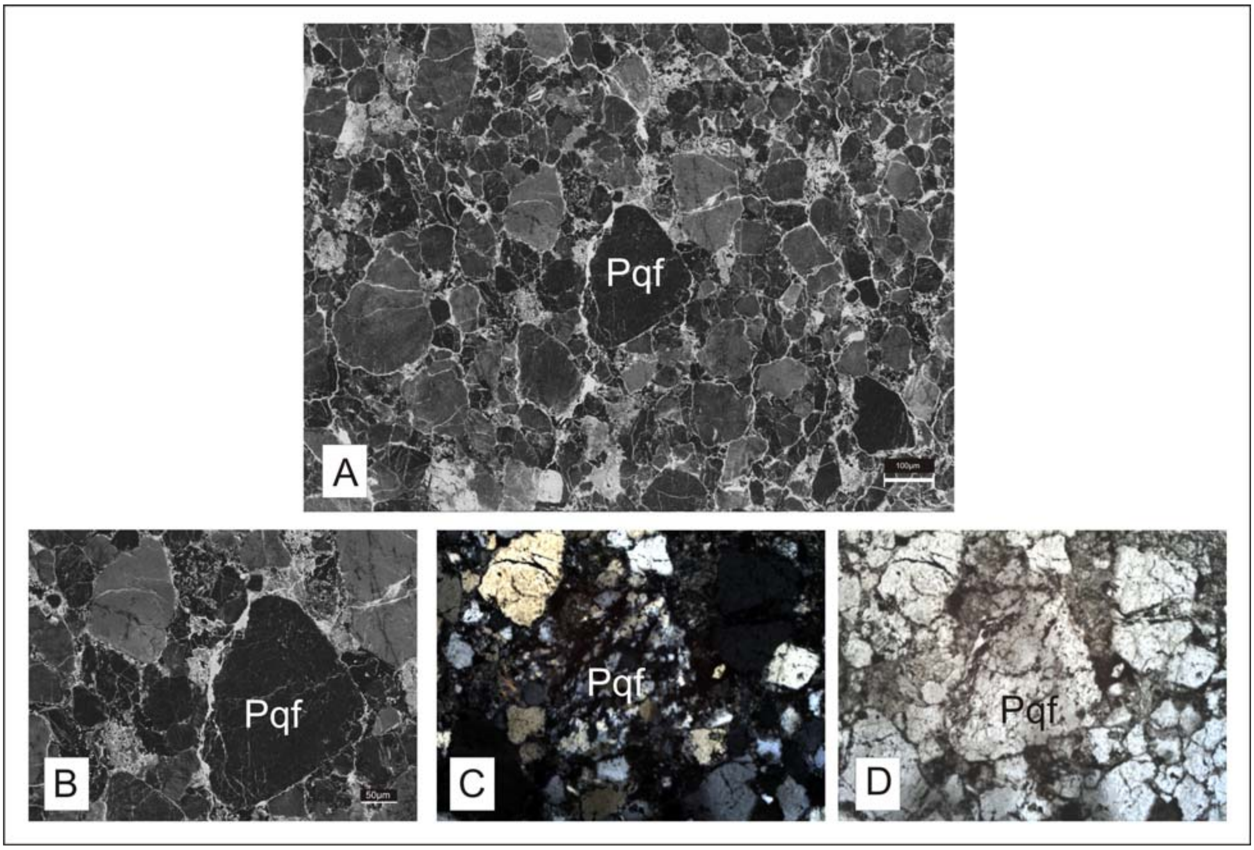

Figure 18. Sample CRQ32. Pqf (polycrystalline quartz fine grained) A = SEM-CL image low magnification, B = SEM-CL image high magnification C=Cross polarized light image D= Plain polarized light image

The fine-grained polycrystalline quartz grain illustrated in figure 18, under thin section appears slightly metamorphosed, with the quartz crystals within the grain seeming slightly elongate and ‘stretched out’. Cracks within the grains internal structure as observed in figure 18B, may represent tectonically deformed quartz, due to the fracturing-like nature. The siltstone lithic imaged in figure 19 appears fractured under SEM-CL, however these fractures seem to develop into fractures that affect the surrounding grains, and must therefore have occurred post-deposition.

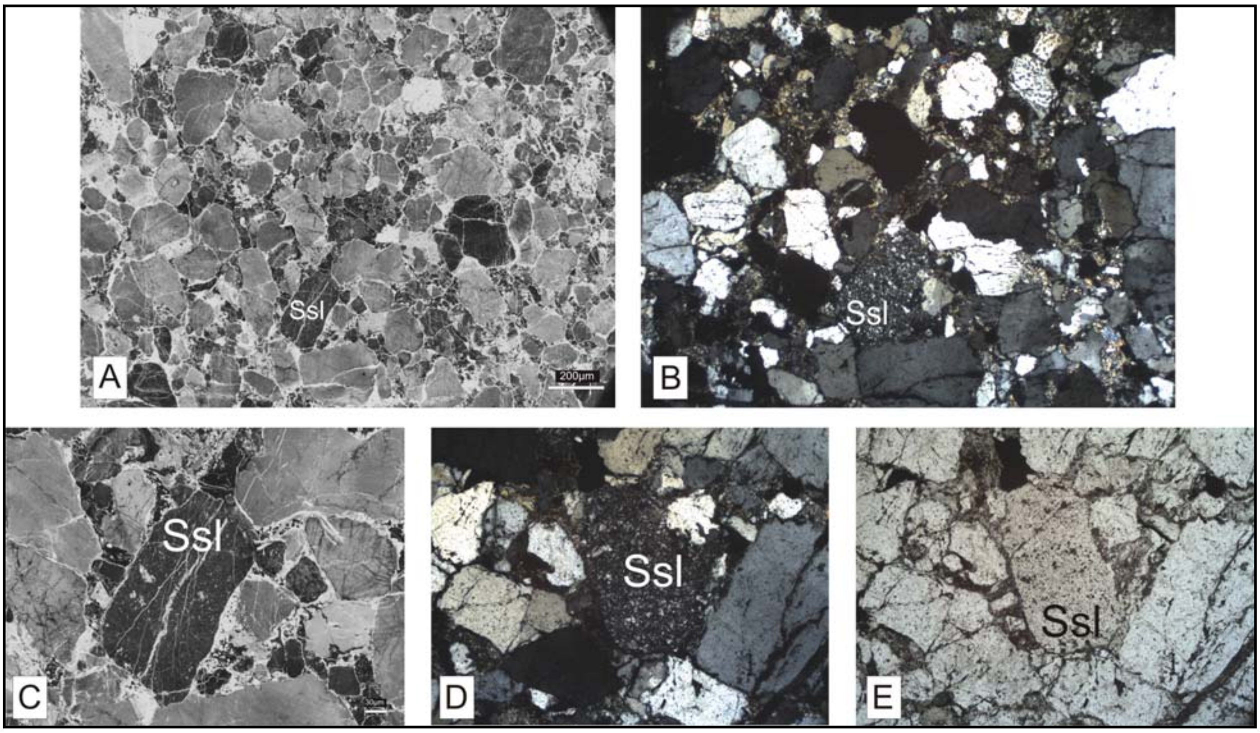

Figure 19. Sample CRQ32. Ssl (siltstone lithic) A = SEM-CL image low magnification, B = Cross polarized light image low magnification C= SEM-CL image high magnification C=Cross polarized light image high magnification D= Plain polarized light image

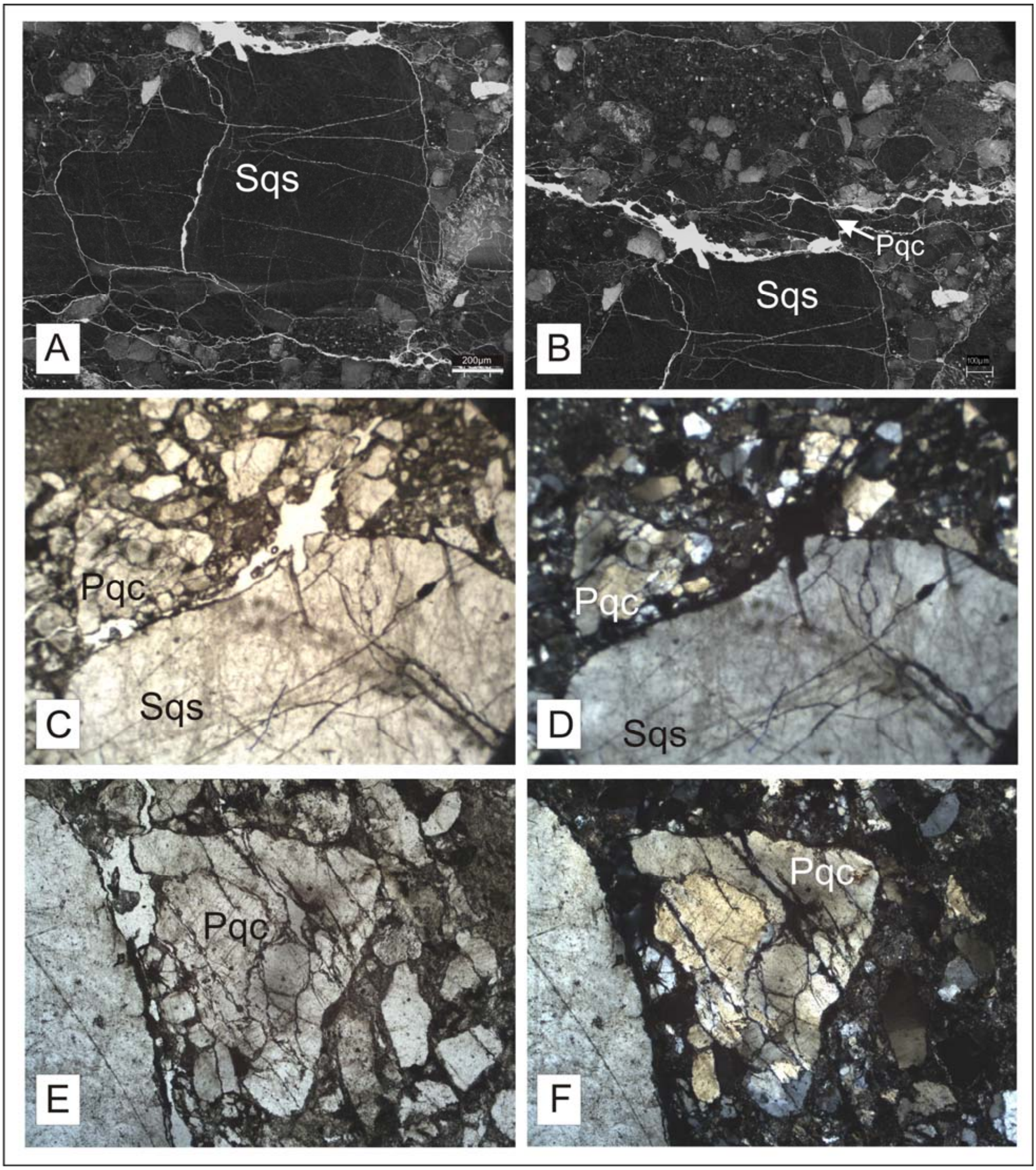

Figure 20. Sample R23/81, Sqs (Single quartz straight extinction) Pqc (polycrystalline quartz coarse grained) A = SEM-CL image with Sqs, B = SEM-CL image with Sqs and Pqc, C = Plain polarized light image of Sqs D= Cross polarized light image of Sqs, E= Plain polarized light image of Pqc, F= Cross polarized light image of Pqc

5.2.2 Sample R23/81

Figures 20 and 21 illustrate the more coarse-grained grain size of the Reilly Conglomerate to that of the clasts in the Camp Ridge Quartzite (figures 16, 17, 18 and 19). A single quartz crystal with straight extinction is observed in figure 20. Fractures within this crystal are apparent in both SEM-CL and petrographic imagery. The majority of the fracturing is constrained within the crystal itself; however, some post-depositional fracturing is also visible in the surrounding sediments. Due to the straight extinction of this crystal and the fracturing observed within its internal fabric, this crystal is most likely to have a plutonic origin.

A coarse polycrystalline quartz grain is observed in figure 9E and 9F. This clast also exhibits multiple fractures occurring within its internal fabric, as observed by the SEM-CL, however, unlike the single quartz crystal observed in figure 20A, 20B ,20C and 20D, the fractures within this grain appear to radiate out to the surrounding sediments, thus implying post-deposition deformation.

A single quartz crystal with undoluse extinction is illustrated in figure 21. Under SEM-CL imagery, the quartz crystal appears to have an intricate internal fabric, with apparent cross-hatching. These semiparallel CL-dark lines are indicative of shearing within the crystal(Boggs & Krinsley 2006).

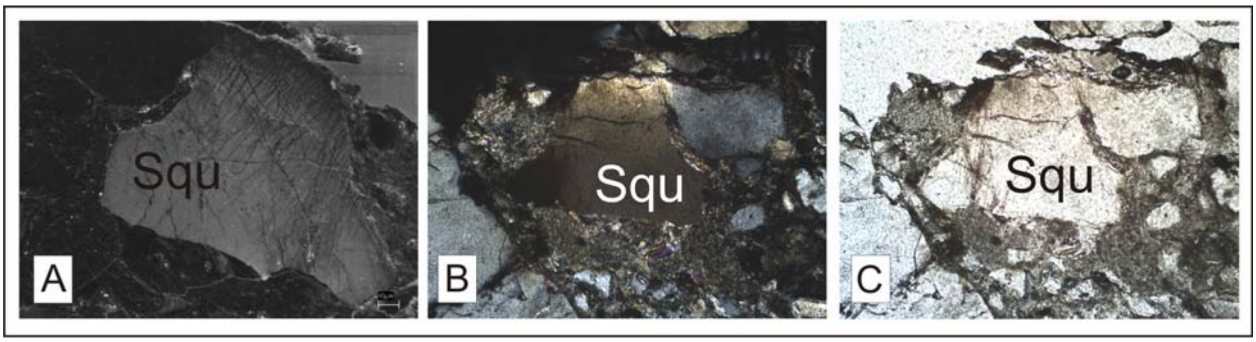

Figure 6 Sample R23/81, Squ (Single quartz, undulose extinction) A = SEM-CL image, B=Cross polarized light image C= Plain polarized light image

6. Discussion

The rocks represented in the Leap Year Group illustrated in this report signify highly quartzose rocks with slightly varying compositions. The features observed in the SEM-CL imagery, combined with thin section analysis, suggest that much of the quartz present within the seven samples examined is either from a plutonic or metamorphic source area. The quartz populations represented in figure 14 further reinforces this, however the ultimate origin of detrial quartz is subject to considerable uncertainty.

Sample CRQ30 is characterised by significant variations in single crystal straight extinction quartz clasts when compared to the other 5 Camp Ridge Quartzite samples. This could be due to the slightly more poorly sorted nature of this sample; however, this sample was taken at the same locality as CRQ32, but has notably different composition Sample R23/81 also has a different composition from the Camp Ridge Quartzite samples, and contains significantly more lithic clasts, the majority of which are metamorphic in nature.

7. Conclusion

The quartz-rich rock samples, CRQ2, CRQ6, CRQ9, CRQ10, CRQ30, CRQ32 and R23/81 are inferred to originate from recycled orogen. Metamorphic quartz and schist was found in all of the seven samples studied, Geochemical plots indicate that these rock samples have originated from a metamorphic terrene. The most likely source for these metamorphic clasts is the adjacent Wilson terrane: as ltihologies observed within the Bowers and Robertson Bay terranes are unlikely to have provided the source rocks for the Leap Year Group.

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